AMENDMENTS TO THE SPECIFICATION

Please amend the title, which is found on page 1 and on page 17, to read "ENGINE CONTROL SYSTEM, VEHICLE HAVING THE SAME, METHOD FOR CALCULATING COMBUSTION CENTER OF GRAVITY, AND METHOD OF CONTROLLING ENGINE".

Please replace paragraph [0002] with the following amended paragraph:

[0002] The present invention relates to an engine control system, a vehicle having the same, a method for calculating the [[fuel]] combustion center of gravity of an engine, and a method for controlling an engine.

Please replace paragraph [0008] with the following amended paragraph:

[0008] Another aspect of an embodiment of the present invention relates to a method for calculating a [[fuel]] combustion center of gravity of an engine. The method comprises: measuring a negative ion current in a combustion chamber of the engine; determining a first crank angle at which an increase rate of the negative ion current relative to the engine crank angle exceeds a first specified value; determining a second crank angle at which the increase rate becomes a second specified value after exceeding the first specified angle; and calculating the [[fuel]] combustion center of gravity from the first crank angle and the second crank angle.

Please replace paragraph [0017] with the following amended paragraph:

[0017] Fig. 6 is a graph showing the relationship between engine speed and ignition timing, and [[fuel]] combustion center of gravity and so on.

Please replace paragraph [0018] with the following amended paragraph:

[0018] Fig. 7 is a graph showing the relationship between ignition timing and torque, [[fuel]] combustion center of gravity and so on.

Please replace paragraph [0019] with the following amended paragraph:

[0019] Fig. 8 is a graph showing the relationship between ignition timing and torque, [[fuel]] combustion center of gravity and so on.

Please replace paragraph [0029] with the following amended paragraph:

[0029] The negative ion current generated in the combustion chamber 5 varies as combustion progresses. Specifically, when the ignition plug 14 ignites the air fuel mixture in the combustion chamber 5, a first chemical action is activated. The first chemical reaction causes electrons in atoms or molecules to collide with one another, which generates energy. The atoms

or molecules thus become excited, which causes sufficient heat ~~generation~~ release to shift to an energy state higher than a normal stable state. In the excited state, chemical light emissions in ultraviolet ray spectrum occurs, which results in an increase in positive ions. As a result, the negative ion current in the combustion chamber 5 increases. The negative ion current is collected by the ignition plug 14 (i.e., the negative ion-current probe) and the value detected by the wattmeter 18 is input into the ECU 16.

Please replace paragraph [0030] with the following amended paragraph:

[0030] Fig. 3 shows characteristic curves of negative ion current E and combustion pressure P plotted against crank angles. As shown in Fig. 3, the characteristic of the negative ion current E exhibits almost the same tendency as that of the combustion pressure P. In other words, the negative ion current E peaks as substantially the same crank angle as the combustion pressure P peaks. The negative ion current E can therefore be used as information indicative of changes in combustion pressure P, flame area, or heat ~~generation~~ release.

Please replace paragraph [0032] with the following amended paragraph:

[0032] However, the inventor has realized the following points. Specifically speaking, as has been described, even when the ignition timing is at MBT, the characteristic curve of the negative ion current E varies as the operating state of the engine 1 varies (refer to curves E1 and E2 of Fig. 4), so that the crank angle corresponding to the peak position of the characteristic curve changes. However, crank angles that change little even if the operating state changes can be calculated from a plurality of crank angles corresponding to a plurality of points on the characteristic curve, such as crank angles corresponding to a [[fuel]] combustion center of gravity. In other words, some intersections between a set crank angle and the characteristic curve are generally consistent with respect to the detected negative ion current. Point P0 in Fig. 4 indicates an intersection corresponding to such a crank angle. Controlling based on this crank angle enables flexible response to fluctuations in load, allowing control applicable to wide operating regions without necessarily measuring torque and combustion pressure.

Please replace paragraph [0037] with the following amended paragraph:

[0037] As shown in Figs. 5(a) and 5(b), the negative ion current generating point (the position corresponding to the first crank angle B) generally correlates with the beginning of combustion. This point preferably follows an ignition delay time, which follows the discharge of

the ignition plug 14, and this point preferably is the point at which heat ~~generation~~ release begins by the start of the initial combustion. The peak point thereafter (the position corresponding to the second crank angle C) preferably is substantially the point of maximum heat ~~generation~~ release during combustion. Accordingly, substantially the midpoint thereof is generally estimated to correspond to the [[fuel]] combustion center of gravity.

Please replace paragraph [0038] with the following amended paragraph:

[0038] The substantially middle point between the first crank angle B and the second crank angle C can therefore be regarded as a crank angle (hereinafter, referred to as a third crank angle) G, which generally corresponds to the [[fuel]] combustion center of gravity. Thus, the [[fuel]] combustion center of gravity can be calculated from the first crank angle B and the second crank angle C. As will be described later, when the ignition timing is at MBT, the [[fuel]] combustion center of gravity does not vary greatly even if the load varies. Accordingly, in this embodiment, the ECU 16 presets the crank angle corresponding to the [[fuel]] combustion center of gravity at MBT as a target crank angle, and controls the ignition timing of the igniter 15 so that the third crank angle determined by measuring the negative ion current agrees with the target crank angle.

Please replace paragraph [0039] with the following amended paragraph:

[0039] When the ignition timing is at MBT, the [[fuel]] combustion center of gravity does not vary greatly by load fluctuations. Accordingly, the target crank angle may be set without much variation caused by engine load. In some embodiments, the target crank angle may be a fixed value. On the other hand, the target crank angle may depend on the operating characteristics of the engine 1, or may be appropriately varied on the basis of an operational expression (e.g., function or mathematical equation) or a table containing parameters.

Please replace paragraph [0040] with the following amended paragraph:

[0040] Fig. 6 shows the relationship between engine speed and ignition timing, [[fuel]] combustion center of gravity, and so on. As discussed above, the [[fuel]] combustion center of gravity preferably is calculated from the first crank angle B and the second crank angle C. Referring to Fig. 6, the first crank angle B, the second crank angle C, and the third crank angle G indicate "spark ignition angle", "the end of combustion", and "the [[fuel]] combustion center of gravity", respectively. The interval between A and B indicates an ignition delay period,

and the interval between B and C indicates a combustion period. In this embodiment, the target crank angle corresponding to the [[fuel]] <u>combustion</u> center of gravity preferably is set at about 1-5° before top dead center. The ignition timing is feed-back controlled so that the third crank angle G becomes the target crank angle (1-5° before the top dead center). Depending upon the application, there may be some variation in the target crank angle.

Please replace paragraph [0041] with the following amended paragraph:

[0041] Fig. 7 shows the relationship between ignition timing and torques and [[fuel]] <u>combustion</u> center of gravity, and so on. As shown in Fig. 7, the torque depends on ignition timing, and becomes the maximum when the ignition timing is at MBT. On the other hand, as the ignition timing advances to the top dead center, the [[fuel]] <u>combustion</u> center of gravity shifts from the position of after top dead center to the position of before top dead center. The torque therefore increases as the [[fuel]] <u>combustion</u> center of gravity moves from the position of after top dead center to the position of before top dead center, and becomes the maximum when the [[fuel]] <u>combustion</u> center of gravity is about at 2-3° before the top dead center, and in turn decreases as the [[fuel]] <u>combustion</u> center of gravity moves toward the before top dead center.

Please replace paragraph [0042] with the following amended paragraph:

[0042] The graph shows that when the ignition timing is controlled so that the third crank angle G (a crank angle corresponding to the [[fuel]] <u>combustion</u> center of gravity) becomes about 2-3° before top dead center, the ignition timing becomes about 35-36° before top dead center, so that the ignition timing generally agrees with MBT.

Please replace paragraph [0046] with the following amended paragraph:

[0046] Under the same conditions of bore/stroke ratio and connecting rod ratio (λ), the combustion speed changes as the rotation speed and load of the engine 1 change, so that the first crank angle B and the second crank angle C determined from the negative ion current changes. However, the third crank angle G corresponding to the [[fuel]] <u>combustion</u> center of gravity is held substantially constant at MBT.

Please replace paragraph [0047] with the following amended paragraph:

[0047] Conventionally, heat ~~generation~~ <u>release</u> has been estimated from pseudo combustion mass ratio converted from combustion pressure. According to the estimation, about 30% of the entire heat ~~generation~~ <u>release</u> distribution at MBT has been estimated to be located

before top dead center, while the remaining 70% has been estimated to be located after top dead center, and the [[fuel]] combustion center of gravity has been estimated to be located after top dead center.

Please replace paragraph [0048] with the following amended paragraph:

[0048] However, by the method for calculating [[fuel]] combustion center of gravity according to the embodiment, the [[fuel]] combustion center of gravity is in the vicinity of top dead center, or more specifically, 1-5° before top dead center. The difference may be by the following reasons: most of negative ions during combustion generate at the excitation of cool flame and blue flame. However, the heat ~~generation~~ release determined from combustion pressure is the result of light emission of amplitude transition, such as flaming reaction after cool flame and blue flame, or solid-state radiation around infrared rays. Accordingly, the conventional method takes little thought of the excitation, so that the [[fuel]] combustion center of gravity determined from combustion pressure may be delayed behind the [[fuel]] combustion center of gravity based on the negative ion current as in the embodiment.

Please replace paragraph [0049] with the following amended paragraph:

[0049] The control method according to one embodiment of the present invention is a method of controlling the engine 1 by measuring a negative ion current, which is unpaired electrons, during true combustion and controlling the engine 1 on the basis of the negative ion current, not by estimating an instantaneous value of the thermal conductivity of combustion gas from combustion pressure as in the past. Thus, the embodiment can reduce errors in calculating the [[fuel]] combustion center of gravity, thus increasing control accuracy. Also, the embodiment can facilitate control of the engine 1 without a dedicated sensor in the combustion chamber 5.

Please replace paragraph [0051] with the following amended paragraph:

[0051] The [[fuel]] combustion center of gravity by the negative ion current varies significantly at flame off due to exhaust gas recirculation (EGR) in which exhaust gas is recirculated in intake gas, a lean-burn air-fuel ratio state, or a stratified-charge combustion state. Thus, it is also possible to control the EGR rate and air-fuel ratio on the basis of the fluctuations of the [[fuel]] combustion center of gravity per unit time to prevent flame off. In short, the

control according to the invention may also be used to reduce or prevent the flame off of the engine 1.

Please replace paragraph [0052] with the following amended paragraph:

[0052] For EGR (since the structure for EGR is well known, a description thereof will be omitted), it is possible to calculate a third crank angle corresponding to the [[fuel]] combustion center of gravity by the above-described method, and calculate the fluctuation of the third crank angle, and to control the EGR rate such that the EGR rate is decreased with increases in the sensed fluctuations. This enables control of the EGR rate without a specific sensor and can reduce or prevent flame off of the engine 1.

Please replace paragraph [0053] with the following amended paragraph:

[0053] It is also possible to calculate a third crank angle corresponding to the [[fuel]] combustion center of gravity by the above-described method, and calculate the fluctuation of the third crank angle, and to control the open-close timing of the intake valve 9 and the exhaust valve 10 of the engine 1 so that the overlap period of the intake valve 9 and the exhaust valve 10 decreases with increasing fluctuation. This enables control of valve timing without a specific sensor and can prevent flame off of the engine 1.

Please replace paragraph [0054] with the following amended paragraph:

[0054] According to one embodiment, ignition timing can be correlated to MBT under a variety of operating states, including decreased combustion speed, thereby improving fuel efficiency, decreasing exhaust gas, and increasing drivability. Also, with a variable valve timing mechanism that controls the lift amount and open-close timing of an intake valve or when engine load conditions, such as rotation speed and throttle opening, are simply varied, [[fro]] for example, the ignition timing can easily be adjusted to MBT, allowing an optimum or preferable combustion state to be achieved. Also, controlling ignition timing so that [[fuel]] combustion center of gravity is delayed behind MBT can reduce or eliminate knocking and reduce the generation of NOx components in the exhaust gas.

Please replace paragraph [0053] with the following amended paragraph:

[0055] The calculation of the [[fuel]] combustion center of gravity and operation control according to the embodiment are based on the characteristic of negative ion current for a crank angle sensed by the crank-angle sensor 19. However, the "crank angle" of the invention is

nothing but a parameter indicative of the process of combustion; parameters that may be technical equivalents or proxies to the crank angle can also be regarded as the "crank angle". This is because such parameters have generally one-to-one correspondence with the crank angle. Accordingly, for example, it is also possible to specify the rising point of negative ion current on the basis of the actual crank angle, while specifying the peak point on the basis of another parameter (e.g., elapsed time) other than the actual crank angle.